The Handbook of Portfolio Mathematics

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The Handbook of Portfolio Mathematics

Formulas for Optimal Allocation & Leverage

RALPH VINCE

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"You must not be extending your empire while you are at war or run into unnecessary dangers. I am more afraid of our own mistakes than our enemies' designs."

—Pericles, in a speech to the Athenians during the Peloponnesian War, as represented by Thucydides

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Contents

Preface	**xiii**
Introduction	**xvii**
PART I Theory	**1**
CHAPTER 1 The Random Process and Gambling Theory	**3**
Independent versus Dependent Trials Processes	**5**
Mathematical Expectation	**6**
Exact Sequences, Possible Outcomes, and the Normal Distribution	**8**
Possible Outcomes and Standard Deviations	**11**
The House Advantage	**15**
Mathematical Expectation Less than Zero Spells Disaster	**18**
Baccarat	**19**
Numbers	**20**
Pari-Mutuel Betting	**21**
Winning and Losing Streaks in the Random Process	**24**
Determining Dependency	**25**
The Runs Test, Z Scores, and Confidence Limits	**27**
The Linear Correlation Coefficient	**32**
CHAPTER 2 Probability Distributions	**43**
The Basics of Probability Distributions	**43**
Descriptive Measures of Distributions	**45**
Moments of a Distribution	**47**
The Normal Distribution	**52**

10.1002/9781119201762.fmatter, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/9781119201762.fmatter, Wiley Online Library on [01/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

The Central Limit Theorem 52
Working with the Normal Distribution 54
Normal Probabilities 59
Further Derivatives of the Normal 65
The Lognormal Distribution 67
The Uniform Distribution 69
The Bernoulli Distribution 71
The Binomial Distribution 72
The Geometric Distribution 78
The Hypergeometric Distribution 80
The Poisson Distribution 81
The Exponential Distribution 85
The Chi-Square Distribution 87
The Chi-Square "Test" 88
The Student's Distribution 92
The Multinomial Distribution 95
The Stable Paretian Distribution 96

CHAPTER 3 Reinvestment of Returns and Geometric Growth Concepts 99

To Reinvest Trading Profits or Not 99
Measuring a Good System for Reinvestment—The Geometric Mean 103
Estimating the Geometric Mean 107
How Best to Reinvest 109

CHAPTER 4 Optimal *f* 117

Optimal Fixed Fraction 117
Asymmetrical Leverage 118
Kelly 120
Finding the Optimal *f* by the Geometric Mean 122
To Summarize Thus Far 125
How to Figure the Geometric Mean Using Spreadsheet Logic 127
Geometric Average Trade 127

10.1002/9781119201762.fmatter, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/9781119201762.fmatter, Wiley Online Library on [01/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

A Simpler Method for Finding the Optimal *f* 128
The Virtues of the Optimal *f* 130
Why You Must Know Your Optimal *f* 132
Drawdown and Largest Loss with *f* 141
Consequences of Straying Too Far from the Optimal *f* 145
Equalizing Optimal *f* 151
Finding Optimal *f* via Parabolic Interpolation 157
The Next Step 161
Scenario Planning 162
Scenario Spectrums 173

CHAPTER 5 Characteristics of Optimal *f* 175

Optimal *f* for Small Traders Just Starting Out 175
Threshold to Geometric 177
One Combined Bankroll versus Separate Bankrolls 180
Treat Each Play as If Infinitely Repeated 182
Efficiency Loss in Simultaneous Wagering or Portfolio Trading 185
Time Required to Reach a Specified Goal and the Trouble with Fractional *f* 188
Comparing Trading Systems 192
Too Much Sensitivity to the Biggest Loss 193
The Arc Sine Laws and Random Walks 194
Time Spent in a Drawdown 197
The Estimated Geometric Mean (or How the Dispersion of Outcomes Affects Geometric Growth) 198
The Fundamental Equation of Trading 202
Why Is *f* Optimal? 203

CHAPTER 6 Laws of Growth, Utility, and Finite Streams 207

Maximizing Expected Average Compound Growth 209
Utility Theory 217
The Expected Utility Theorem 218
Characteristics of Utility Preference Functions 218

10.1002/9781119201762.fmatter, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/9781119201762.fmatter, Wiley Online Library on [01/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Alternate Arguments to Classical Utility Theory 221
Finding Your Utility Preference Curve 222
Utility and the New Framework 226

CHAPTER 7 Classical Portfolio Construction 231

Modern Portfolio Theory 231
The Markowitz Model 232
Definition of the Problem 235
Solutions of Linear Systems Using Row-Equivalent Matrices 246
Interpreting the Results 252

CHAPTER 8 The Geometry of Mean Variance Portfolios 261

The Capital Market Lines (CMLs) 261
The Geometric Efficient Frontier 266
Unconstrained Portfolios 273
How Optimal *f* Fits In 277
Completing the Loop 281

CHAPTER 9 The Leverage Space Model 287

Why This New Framework Is Better 288
Multiple Simultaneous Plays 299
A Comparison to the Old Frameworks 302
Mathematical Optimization 303
The Objective Function 305
Mathematical Optimization versus Root Finding 312
Optimization Techniques 313
The Genetic Algorithm 317
Important Notes 321

CHAPTER 10 The Geometry of Leverage Space Portfolios 323

Dilution 323
Reallocation 333
Portfolio Insurance and Optimal *f* 335
Upside Limit on Active Equity and the Margin Constraint 341

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f Shift and Constructing a Robust Portfolio 342
Tailoring a Trading Program through Reallocation 343
Gradient Trading and Continuous Dominance 345
Important Points to the Left of the Peak in the $n + 1$ Dimensional Landscape 351
Drawdown Management and the New Framework 359

PART II Practice 365

CHAPTER 11 What the Professionals Have Done 367

Commonalities 368
Differences 368
Further Characteristics of Long-Term Trend Followers 369

CHAPTER 12 The Leverage Space Portfolio Model in the Real World 377

Postscript 415

Index 417

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Preface

It's always back there, bubbling away. It seems I cannot shut off my mind from it. Every conversation I ever have, with programmers and traders, engineers and gamblers, Northfield Park Railbirds and Warrensville Workhouse jailbirds—those equations that describe these very things are cast in this book.

Let me say I am averse to gambling. I am averse to the notion of creating risk where none need exist, averse to the idea of attempting to be rewarded in the absence of creating or contributing something (or worse yet, taxing a man's labor!). Additionally, I find amorality in charging or collecting interest, and the absence of this innate sense in others riles me.

This book starts out as a compilation, cleanup, and in some cases, reformulation of the previous books I have written on this subject. I'm standing on big shoulders here. The germ of the idea of those previous books can trace its lineage to my good friend and past employer, Larry Williams. In the dust cloud of his voracious research, was the study of the Kelly Criterion, and how that might be applied to trading. What followed over the coming years then was something of an explosion in that vein, culminating in a better portfolio model than the one which is still currently practiced.

For years now I have been away from the markets—intentionally. In a peculiar irony, it has sharpened my bird's-eye view on the entire industry. People still constantly seek me out, bend my ears, try to pick my hollow, rancid pumpkin about the markets. It has all given me a truly gigantic field of view, a dizzying phantasmagoria, on who is doing what, and how.

I'd like to share some of that with you here.

We are not going to violate anyone's secrets here, realizing that most of these folks work very hard to obtain what they know. What I will speak of is generalizations and commonalities in what people are doing, so that we can analyze, distinguish, compare, and, I hope, arrive at some well-founded conclusions.

But I am not in the markets' trenches anymore. My time has been spent on software for parametric geometry generation of industrial componentry and "smart" robots that understand natural language and can go out and do

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things like perform research for me, come back, draw inferences, and discuss their findings with me. These are wonderful endeavors for me, allowing me to extend my litany of failures.

Speaking of which, in the final section of this text, we step into the near-silent, blue-lit morgue of failure itself, dissecting it both in a mathematical and abstract sense, as well as the real-world one. In this final chapter, the two are indistinguishable.

When we speak of the *real world*, some may get the mistaken impression that the material is easy. It is not. That has not been a criterion of mine here. What has been a criterion is to address the real-world application of the previous three books that this book incorporates. That means looking at the previous material with regard to failure, with regard to drawdown. Money managers and personal traders alike tend to have utility preference curves that are incongruent with maximizing their returns. Further, I am aware of no one, nor have I ever encountered any trader, fund manager, or institution, who could even tell you what his or her utility preference function was. This is a prime example of the chasm—the disconnect—between theory and real-world application.

Historically, risk has been defined in theoretical terms as the variance (or semivariance) in returns. This, too, is rarely (though in certain situations) a desired proxy for risk. Risk is the chance of getting your head handed to you. It is not, except in rare cases, variance in returns. It is not semivariance in returns; it is not determined by a utility preference function. Risk is the probability of being ruined. Ruin is touching or penetrating a lower barrier on your equity. So we can say to most traders, fund managers, and institutions that risk is the probability of touching a lower barrier on equity, such that it would constitute ruin to someone. Even in the rare cases where variance in returns is a concern, risk is still primarily a drawdown to a lower absorbing barrier.

So what has been needed, and something I have had bubbling away for the past decade or so, is a way to apply the optimal *f* framework within the real-world constraints of this universally regarded definition of risk. That is, how do we apply optimal *f* with regard to risk of ruin and its more familiar and real-world-applicable-cousin, risk of drawdown?

Of course, the concepts are seemingly complicated—we're seeking to maximize return for a given level of drawdown, not merely juxtapose returns and variance in returns. Do you want to maximize growth for a given level of drawdown, or do you want to do something easier?

So this book is more than just a repackaging of previous books on this subject. It incorporates new material, including a study of correlations between pairwise components in a portfolio (and *why* that is such a bad idea). Chapter 11 examines what portfolio managers have (not) been doing with regards to the concepts presented in this book, and Chapter 12 takes

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the new Leverage Space Portfolio Model and juxtaposes it to the probability of a given drawdown to provide a now-superior portfolio model, based on the previous chapters in this book, and applicable to the real world.

I beg the reader to look at everything in this text—as merely my articulation of something, and not an autocratic dictation. Not only am I not infallible, but also my real aim here is to engage you in the study of something I find fascinating, and I want to share that very raw joy with you. Because, you see, as I started out saying, it's always back there, bubbling away—my attraction to those equations on the markets, pertaining to allocation and leverage. It's not a preoccupation with the markets, though—to me it could be the weather or any other dynamic system. It is the allure of nailing masses and motions and relationships with an equation.

Rapture!

That is my motivation, and that is why I can never shut it off. It is that very rapture that I seek to share, which augments that very rapture I find in it. As stated earlier, I stand on big shoulders. My hope is that my shoulders can support those who wish to go further with these concepts.

This book covers my thinking on these subjects for more than two and a half decades. There are a lot of people to thank. I won't mention them, either—they know who they are, and I feel uneasy mentioning the names of others here in one way or another, or others in the industry who wish to remain nameless. I don't know how they might take it.

There is one guilty party, however, whom I *will* mention—Rejeanne. This one, finally, is for you.

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Chagrin Falls, Ohio
August 2006

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Introduction

This is a book in two distinct parts. Originally, my task was to distill the previous three books on this subject into one book. In effect, Part I comprises that text.

It's been reorganized, rehashed, and reworked to resemble the original texts while creating a contiguous path of reasoning, which takes us from the basic gambling theory and statistics, through the introduction of the Kelly criterion, optimal f, and finally onto the Leverage Space Portfolio Model for multiple-simultaneous positions.

The Leverage Space Portfolio Model addresses allocations and leverage. Often these are two distinct facets, but herein they refer to the same thing. *Allocation* is the *relative* leverage between multiple portfolio components. Thus, when we speak of *leverage*, we are also speaking of *allocation*, and vice versa.

Likewise, *money management* and *portfolio construction*, as practiced, don't necessarily refer to the same exercise, yet in this text, they do. Collectively, whatever the endeavor of risk, be it a bond portfolio, a commodities fund, or a team of blackjack players invading a casino, the collective exercise will be herein referred to as *allocation*.

I have tried to keep the geometric perspective on these concepts, and keep those notions about them intact. The first section is necessarily heavy on math. The first section is purely conceptual. It is about allocation and leverage to maximize returns without respect to anything else.

Everything in Part I was conjured up more than a decade or two ago. I was younger then.

Since that time, I have repeatedly been approached with the question, "How do you apply it?" I used to be baffled by this; the obvious (to me) answer being, "As is."

As used herein, a ln utility preference curve is one that is characteristic of someone who acts so as to maximize the ratio of his or her returns to the risk assumed to do so.

The notion that someone's *utility preference function* could be anything other than ln was evidence of both the person's insanity and weakness.

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I saw it as a means for risk takers to enjoy the rush of their compulsive gambling under the ruse of the academic justification of *utility preference*.

I'm older now (seemingly not tempered with age—you see, I still know the guy who wrote those previous books), but I have been able to at least accept the exercise—the rapture—of working to solve the dilemma of optimal allocations and leverage under the constraint of a utility preference curve that is *not* ln.

By the definition of a ln utility preference curve, given a few paragraphs ago, a sane[1] person is therefore one who is levered up to the optimal f level in a game favorable to him or minimizes his number of plays in a game unfavorable to him. Anyone who goes to a casino and plunks down all he is willing to lose on that trip in one play is not a compulsive gambler. But who does that? Who has that self-control? Who has a utility preference curve that *is* ln?

That takes us to Part II of the book, the part I call the *real-world application* of the concepts illuminated in Part I, because people's utility preference curves are not ln.

So Part II attempts to tackle the mathematical puzzle posed by attempting to employ the concepts of Part I, given the weakness and insanity of human beings. What could be more fun?

* * *

Many of the people who have approached me with the question of "How do you apply it?" over the years have been professionals in the industry. Since, ultimately, their clients are the very individuals whose utility preference curves are not ln, I have found that these entities have utility preference functions that mirror those of their clients (or they don't have clients for long).

Many of these entities have been successful for many years. Naturally, their procedures pertaining to allocation, leverage, and trading implementation were of great interest to me.

Part II goes into this, into what these entities typically do. The best of them, I find, have not employed the concepts of the last chapter except in very rudimentary and primitive ways. There is a long way to go.

Often, I have been criticized as being "all theory—no practice." Well, Part I is indeed all theory, but it *is* exhaustive in that sense—not on portfolio construction in general and all the multitude of ways of performing that, but rather, on portfolio construction in terms of optimal position sizes (i.e., in the vein of an optimal f approach). Further, I did not want Part I to be

[1]Academics prefer the nomenclature "rational," versus "sane." The subtle difference between the two is germane to this discussion.

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a mere republishing, almost verbatim, of the previous books. Therefore, I have incorporated some new material into Part I. This is material that has become evident to me in the years since the original material was published.

Part II is entirely new. I have been fortunate in that my first exposure to the industry was as a margin clerk. I had an opportunity to observe a sizable universe of ways people go about doing things in this business. Later, thanks to my programming abilities, from which the other books germinated, I had exposure to many professionals in the industry, and was often privy to how they practiced things, or was in a position where I could reverse-engineer it. I have had the good fortune of being on a course that has afforded me a bird's-eye view of the way people practice their allocation, leverage, and trading implementations in this business. Part II is derived from that high-altitude bird's-eye view, and the desire to provide a real-world implementation of the concepts of Part I—that is, to make them applicable to those people whose utility preference functions are not ln.

* * *

Things I have written of in the past have received a good deal of criticism over the years. I welcome it, and a chance to address it. To me, it says people are thinking about these ideas, trying to mold them further, or remold those areas where I may have been wrong (I'm not so much interested in being "right" about any of this as I am about "this"). Though I have not consciously intended that, this book, in many ways, answers some of those criticisms.

The main criticism was that it was too theoretical with no real-world application. The criticism is well founded in the sense that drawdown was all but ignored. For better or worse, people and institutions never seem to have utility functions that are ln. Yet, nearly all utility functions of people and institutions are ln within a drawdown constraint. That is, they seek to maximize the ratio of returns to risk (drawdown) within a certain drawdown. That disconnect between what I have written in the past has now, more than a decade later, been resolved.

A second major criticism is that trading at optimal f is too wild for any mere human. I know of no professional funds that have traded at the optimal f levels. I have known people who have traded at optimal f, usually for short periods of time, in only a single market, before panicking in a drawdown. There it is again: drawdown. You see, it wasn't so much this construct of their utility preference curve (talk about too theoretical!) as it was their drawdown that was incongruent with their trading at the optimal f level.

If you are getting the notion that we will be looking into the nature of drawdown later on in this book, when we discuss what I have been doing in terms of working on this material for the past decade-plus, you're right. We're going to look at drawdown herein beyond what anyone has.

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Which takes us to the third major criticism, being that optimal f or the Leverage Space Model allocates without respect to drawdown. This, too, has now been addressed directly in Chapter 12. However, as we will see in that chapter, drawdown is, in a sequence of independent trials, but one permutation of many permutations. Thus, to address drawdown, one must address it in those terms.

The last major criticism has been that regarding the complexity of calculation. People desire a simple solution, a heuristic, something they could perform by hand if need be.

Unfortunately, that was not the case, and that desire of others is now something even more remote. In the final chapter, we can see that one must perform millions of calculations (as a sample to billions of calculations!) in order to derive certain answers.

However, such seemingly complex tasks can be made simple by packaging them up as black-box computer applications. Once someone understands what calculations are performed and why, the machine can do the heavy lifting. Ultimately, that is even simpler than performing a simple calculation by hand.

If one can put in the scenarios, their outcomes, and probability of occurrence—their joint probabilities of occurrence with other scenarios in other scenario spectrums—one can feed the machine and derive that number which satisfies the ideal composition, the optimal allocations and leverage among portfolio components to satisfy that ln utility preference function within a certain drawdown constraint.

To be applicable to the real world, a book like this should, it would seem, be about trading. This is *not* a book on how to trade the markets. (This makes the real-world application section difficult.) It is about how very basic, mathematical laws are working on us—you and me—when we engage in a stream of risk-related outcomes wherein we don't have control over those outcomes. Rather, we have control only over the relative impacts on us. In that sense, the mathematics applies to us in trading.

I don't want to pretend to know a thing about trading, really. Just as I am not an academic, I am also not a trader. I've been around and worked for some amazing traders—but that doesn't mean I am one.

That's *your* domain—and why you are reading this book: To augment the knowledge you have about trading vis-à-vis cross-pollination with these *outside* formulas. And if they are too cumbersome, or too complicated, please don't blame me. I wish they were simply along the lines of $2 + 2$. But they are not.

This is not by my design. When you trade, you are somewhat trying to intuitively carve your way along the paths of these equations, yet you are oblivious to what the equations are. You are, for instance, trying to maximize

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your returns within a certain probability of a given drawdown over the next period.

But you don't really have the equations to do so. Now you do. Don't blame me if you find them to be too cumbersome. These formulas are what we seek to know—and somehow use—as they apply to us in trading, whether we acknowledge that or not. I have heard ample criticism about the difficulties in applications. In this text, I will attempt to show you what others are doing *compared* to using these formulas. However, these formulas are at work on everyone when they trade. It is in the disparity between the two that your past criticisms of me lie; it is in that very disparity that my criticisms of you lie.

When you step up to the service line and line up to serve to my backhand, say, the fact that gravity operates with an acceleration of 9.8 meters per second squared applies to you. It applies to your serve landing in the box or not (among other things), whether you acknowledge this or not. It is an explanation of how things work more so than how to work things. You are trying to operate within a world defined by certain formulas. It does not mean you can implement them in your work, or that, because you cannot, they are therefore invalid. Perhaps you can implement them in your work. Clearly, if you could, without expense to the other aspects of "your work," wouldn't it be safe to say, then, that you certainly wouldn't be worse off?

And so with the equations in the book. Perhaps you can implement them—and if you can, without expense to the other aspects of your game, then won't you be better off? And if not, does it invalidate their truths any more than a tennis pro who dishes up a first serve, oblivious to the 9.8 m/s^2 at work?

* * *

This is, in its totality, what I know about allocations and leverage in trading. It is the sum of all I have written of it in the past, and what I have savored over the past decade-plus. As with many things, I truly love this stuff. I hope my passion for it rings contagiously herein. However, it sits as dead and cold as any inanimate abstraction. It is only your working with these concepts, your application and your critiques of them, your volley back over the net, that give them life.

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